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Design, construction and performance evaluation of an *Àmàlà* making machine

E.A. Ajav*, M.A. Mankinde

Department of Agricultural and Environmental Engineering, Faculty of Technology, University of Ibadan, Nigeria

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Abstract

An *àmàlà* making machine was designed and constructed to make *àmàlà* preparation an easy one and remove the fatigue usually experienced during manual preparation. The machine frame was from galivanised and stainless steel materials and it is capable of preparing *àmàlà* of averagely 1.074–2.68 kg by weight. It has two compartments, the heating and stirring compartments. The stirrer has six flat paddles arranged asymmetrically and powered by a 0.94 HP electric motor. The performance evaluation of the machine revealed that the output by weight is significantly different ($P<0.5$) indicating that weight is not equal due to different input. There was reduction in weight with decrease in temperature of the paste from 90–66 °C residence time 5–2.5 min and quantity of heat stored by the paste from 210.16–8.64 KJ as the input reduced. The density of the paste increases as the volume of water reduces (1223.83 kg/m^3 at 1.8 Litre of water to 2303.33 kg/m^3 at 0.6 Litre of water). Although, pastes produced at various ratio of yam flour and water are adjudged suitable by panellists in terms of colour, taste, aroma during sensory evaluation test, but 0.5 kg of flour produced overall acceptable paste with 1.8 Litre (maximum pot capacity), while 0.35 kg of flour produces overall acceptable paste with 0.6 Litre (minimum pot capacity)in term of modability, and texture.

1. Introduction

Àmàlà is a thick brown paste or porridge made from yam, which had been peeled, cleaned, dried and then blended into flour. It is the most popular among other foods like *eba* and pounded yam proudly found among Yoruba speaking people. It is prepared by mixing flour of yam or cassava called *èlùbó* to boiling water, then stirred very well to mix and smoothen it. The market of yam flour has increased considerably in the recent 30 years in such a way that *àmàlà* is more frequently consumed in urban areas of Nigeria and Benin (Cotonou in particular) than very traditional pounded yam (Mestres et al, 2004).

It cannot be eaten alone but complemented with any kind of stew or soup especially among those that are found in south west Nigeria like, *gbegiri*, *ewedu*, *egusi*. Among these two types of "*àmàlàs*" (i.e. *àmàlà lafun* made from cassava flour and *àmàlà gidi* made from yam flour) the one made with yam flour called *àmàlà isu* is widely accepted and even used in occasions.

The *àmàlà isu* which the machine is designed to prepare involves mixing of yam flour with boiling water. The best yam for yam flour production is *Kokoro* group of white yam (*Discorea rotundata*) cultivars (Mestres et al, 2004; Adedeji, 2010). The tubers are washed, peeled, sliced, parboiled and sun dried. The dried slices are grounded into flour using burr mill, and sieves to obtain finer particle. The addition of the flour to boiling water, when stirred quickly together, gives a smooth paste. The reconstituted flour (known as *Kokonte* in Ghana and *Àmàlà* in Nigeria) is popular for feeding both adults and children, and it is an important source of carbohydrate for many people in yam zone of west Africa (Akissoe et al., 2003).

Meanwhile, to ease the design, some properties of yam flour needed to be known. Adedeji (2010), gave the pH of yam flour to be between 6.25 and 6.93. The bulk density ranges from 0.54 to 0.7 g/ml. The dispersibilty ranges from 66 to 72.5%, water absorption index is within 99.2–245.25% and pasting

*Corresponding author.
E-mail address: ea.ajav@ui.edu.ng (E.A. Ajav).
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property are; peak viscosity 150.83–317.2RVU, trough of the yam flour from 120.62 to 214.38RVU, breakdown of yam flour which ranged from 12.75RVU to 93.46RVU.

Moreover, since *àmàlà* is prepared even manually by mixing of water and flour therefore it is necessary to select appropriate mixing device. Amber et al. (2005) also gave different types of blades as helical blade, that simulates auger, symmetrical and asymmetrical blades which simulate the solid paddle design of a butter churn, angled blade to model industrial mixer propeller design, and hollow blade was created to model blade design of kitchen mixers. Therefore, in this design, symmetrical and asymmetrical blades were selected because both *àmàlà* and butter are in paste form.

Despite the importance of *àmàlà* among south west people of Nigeria, its preparation remains manuall The person preparing the amala is usually subjected to stress during stirring and sweats a lot, which makes the process difficult. Therefore, the need to produce a machine that will prepare *àmàlà* easily and hygienically. This paper therefore report the design, construction and testing of an *àmàlà* making machine.

2. Materials and methods

2.1. The preliminary investigation on making of *Àmàlà*

In the design of an *Àmàlà* making machine, adequate information on the manual processing is required, such as ratio of flour to water, temperature of the paste immediately after preparation, number of turning before a smooth paste is achieved and stirring time.

In other to obtain this information, that is, ratio of flour to water, temperature of the paste immediately after preparation, number of turning before a smooth paste is achieved and stirring time, questionnaire was distributed among 16 women who have been preparing "*àmàlà*" manually on daily basis. The questionnaire was distributed among the housewives and canteen owners living or having their shops located around Idi-Ape and Abayomi areas of Iwo Road, Ibadan. The questionnaires were then examined and necessary information that will help in the design were extracted and recorded accordingly with 8 of the respondents giving information on yam flour paste (*àmàlà isu*) and the other 8 respondents on cassava flour paste (*àmàlà láfún*). The manual preparation of *àmàlà* include, boiling of clean water, addition of flour, removal of the heat source (if it is *àmàlà láfún*), continuous stirring, addition of hot/cold water (if it is *àmàlà isu),* and stir further till required texture/smoothness will be achieved.

2.2. The machine parts and materials used

The machine construction includes materials like, stainless steel flat bar, stainless rod, aluminium pot with cover, electric cooker/heater, an electric motor and a clamping bush.

After construction the machine has major parts like a heating compartment, a cooking pot, an electric motor, control switches and a stirrer. The function of each of the parts is given below.

(i) **Electric cooker/heater:** this is needed to raise the temperature of the water to boiling point, and also supply heat for cooking the food when water is added.
(ii) **Cooking pot:** an aluminium pot is used for preparation of the food, by placing it on the heater to boil the water and prepare the food.
(iii) **Electric motor:** the electric motor is to power the stirrer. The type of electric motor selected is a single phase electric motor. The power produced will be transmitted to the stirrer coupled directly to the motor with the aid of a bushing.
(iv) **The stirrer:** the stirrer comprises of stainless shaft, and the paddles made from stainless flat bars that was welded to the shaft to stir the mixture together. It is necessary to be cautious of the material corrosion due to persistent contact with water in the presence of air, and also because it will be involved in food preparation. Therefore, stainless steel was used for the stirrer due to its resistance to corrosion and readily availability in the market. The choice of flat bar for the paddle is to provide more contact area for the paste stirring, thereby enhance smooth stirring within a short period.

2.3. Design specifications

The major part to design for is the stirrer which includes the shaft and the paddle because every other part can be obtained directly from market. The stresses found in shaft design are torsional stress, and bending stress.

The following assumptions were made:

(i) The material to stir is a semi-solid material
(ii) The shaft diameter is 15 mm (0.015 m)
(iii) The thickness of the paddle is 3 mm
(iv) There are six paddles arranged asymmetrically in pairs with 10mm distance from each pair.

2.3.1. Determination of torsional stress

To mix a semi solid material, as given by Bobic et al. (2011),

The shear stress,

$$\tau = \gamma\,\eta \ldots \tag{1}$$

where, γ = shear rate (s^{-1}); η = viscosity (kg/ms); and, shear rate,

$$\gamma = \frac{4\pi n}{1-k^2} \cdots \tag{2}$$

where, n = speed in revolution per second; k = ratio of the diameter covered by the paddle to the pot diameter (d/D).

Due to the slow speed expected to avoid ball formation in the paste spillage during stirring and to ensure thorough stirring of the mixture, 75 rpm is assumed as the speed of rotation of motor.

A diameter of 0.18 m as the pot diameter and 0.14 m as the diameter covered by the paddle were selected based on dimension of the pot commonly used to prepare *àmàlà* enough for two to four adults.

Therefore, $k = 0.14/0.18 = 0.778$

$$n = 75\text{ rpm} = \left(75/60\right)\text{rps} = 1.25\text{ rev}/s$$

$$\gamma = \frac{4\pi(1.25)}{1-0.778^2} = 39.80\text{ s}^{-1}$$

Adedeji (2010) gave yam flour paste peak viscosity as 200.2 rvu averagely, equivalent to 2.41 kg/ms. Peak viscosity, as the name implies, is the maximum viscosity attained soon after starch slurry becomes viscous due to starch granule swelling and leaching out of soluble component into solution, (Baah et al, 2009)

The shear stress,

$$\tau = (39.80 \times 2.41 \times 9.81)\text{ Pa}$$
$$= 941\text{ Pa}$$

Also,

$$\tau = F/A\ldots \tag{3}$$

where, F=Shear force; A=Area of the paddle side in contact with the paste; $A = (0.008 \times 0.0765)\text{ m}^2 = 6.12 \times 10^{-4}\text{ m}^2$

$$F = \tau A\ldots$$
$$F = 941 \times \left(6.12 \times 10^{-4}\right) = 0.5759\text{ N} \tag{4}$$

Applied torque,

$$T = \frac{63,025\text{ hp}}{\text{rpm}}\ldots \tag{5}$$

Assume the motor power rating is 1 HP

$$T = \frac{63,025 \times 1}{75}$$
$$= 840.33\text{in}-\text{lb}$$
$$= (840.33 \times 0.0254 \times 0.454) = 9.69\text{ N}-\text{m}$$

$$Z' = \frac{\pi D^3}{16}\ldots \tag{6}$$

Z'=Polar section modulus; D=Shaft diameter; =15 mm= 0.015 m; $Z' = \pi \times 0.015^3/16$; $Z' = 6.6268 \times 10^{-7}\text{ m}^3$

Then the torsional stress,

$$\tau = \frac{T}{Z'}$$
$$\tau = \frac{9.69}{6.6268 \times 10^{-7}}$$
$$= 14,622,2442.2\text{ Pa}$$
$$= 14.6\text{ MPa} \tag{7}$$

2.3.2. Determination of torsional angular deflection

The torsional angular deflection can be determined with following equation,

$$\theta = \frac{32\text{TL}}{\text{G}\pi D^4} \tag{8}$$

Where, G=modulus of rigidity (for stainless $G = 87 \times 10^9\text{ N/m}^2$)

$$\theta = \frac{32 \times 9.69 \times 0.22}{87 \times 10^9 \times 0.015^4 \times \pi}$$
$$= \frac{68.22}{13,836.752}$$
$$\theta = \left(4.93 \times 10^{-3}\right)^0/m$$

2.3.3. Determination of bending stress

Force applied by the paste during stirring is the only force acting on the shaft, therefore the resultant force, F=force applied by the paste, the maximum moment,

$$M_\text{m} = \frac{\text{FL}}{4}\ldots \tag{9}$$

where, F=resultant force; L=length of the shaft

$$M_\text{m} = \frac{0.5759 \times 0.22}{4}$$
$$= 0.032\text{ Nm}$$
$$Z = \frac{\pi D^3}{32}$$
$$= \frac{\pi(0.015)^3}{32}$$
$$= 3.3134 \times 10^{-7}\text{ m}^3$$

where, Z=Shaft Rectangular section modulus

Bending Stress,

$$\sigma = \frac{M_\text{m}}{Z}\ldots$$
$$= \frac{0.032}{3.3134 \times 10^{-7}}$$
$$= 96,577.53\text{ Pa}$$
$$= 96.6\text{ KPa} \tag{10}$$

The torsional stress is higher than the bending stress this indicates that the shaft is subjected to torsional stress than bending stress, and the torsional stress does not exceed the allowable stress, which shows that the assumed 1.5 cm diameter of the shaft is appropriate. Also, the torsional angle of deflection is at minimal as it is not up to the maximum deflection which is (0.26)°/m.

2.3.4. Determination of the paddle thickness

Assuming the load is uniformly distributed across the paddle surface (a cantilever beam) with one free end.

Now the maximum deflection,

$$\delta = \frac{\text{FL}^4}{8\text{EI}}\ldots \tag{11}$$

$$\text{I} = \frac{\text{bd}^3}{12}\ldots$$
$$= \frac{0.0765 \times 0.003^3}{12}$$
$$= 1.72125 \times 10^{-4}\text{ m}^4$$
$$\text{E} = 196 \times 10^9\ N/m^2$$
$$\delta = \frac{0.5759 \times 0.0765^4}{8 \times 196 \times 10^9 \times 1.72125 \times 10^{-4}}$$

$$= 7.308 \times 10^{-14}\ \text{m}$$
$$\delta = 7.308071 \times 10^{-11}\ \text{mm} \tag{12}$$

The deflection is 7.308071×10^{-11} mm which is minimal. Therefore, the 3 mm of the paddle thickness is suitable.

2.3.5. Determination of pot capacity

The pot capacity suitable for at least two adults during investigation has the dimensions stated below,

The pot diameter = 0.18 m
The pot height = 0.10 m
But the paste usually covers 0.07 m of 0.10 m of the pot

Therefore,

$$\text{the capacity} = \text{volume} = \frac{\pi D^2 h}{4} \ldots$$

$$V = \frac{\pi (0.18^2) 0.07}{4} = 1.7813 \times 10^{-3}\ \text{m}^3$$
$$V = 1.7813 \times 10^{6}\ \text{mm}^3 \tag{13}$$

The pot capacity that should be used should not be less than 1.7813×10^6 mm^3, that is, 1.78 litres.

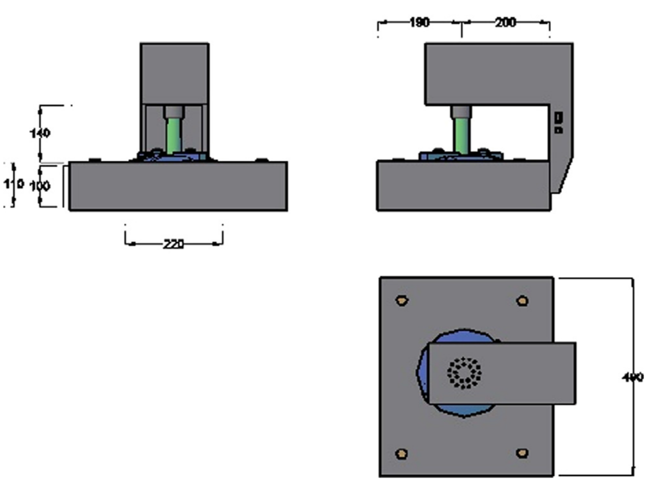


Fig. 1. Orthographic view of the machine.

2.4. The frame

The frame or housing is to cover the heating element and the pot, provides support as well serves as a house for the electric motor. It also serves as a holder to switches that control both the electric motor and the electric stove. It has two pins situated opposite of each other to hold the pot during stirring.

The dimension of the frame base depends on the size of the pot and the electric stove selected. The electric motor determines the size of the upright and the over head frame. To prevent corrosion of the frame, which may occur in the presence of air and water on metal, stainless steel is chosen as the top of the base and other parts are made from galvanized material.

The computer aided drawings in Figs. 1 and 2 shows the orthographic view, and exploded view of the machine respectively.

2.5. Machine description

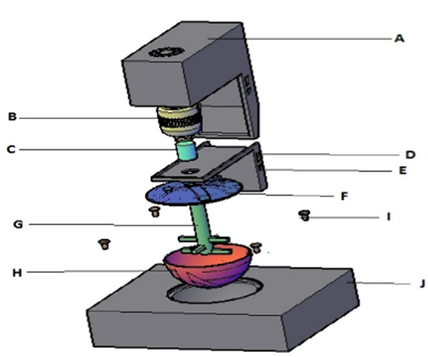
An *àmàlà* making machine that was designed and constructed, it has two major components, which are, heater/boiler on which a pot of 1.8 Litre capacity is resting, and electric motor to power the stirrer. The stirrer comprises of 6 paddles made from flat bar stainless steel arranged asymmetrically, each of the paddles is 10 mm high, 80 mm long and 3 mm thick, the gap between each parallel pairs of the paddle is 10 mm.

The clearance between the paddles and pot wall is 5 mm to avoid the seizure of the stirrer during operation and damage that it may cause to the wall of the pot. A flat stainless steel plate of diameter 45 mm was welded to the free end (i.e. the base) of the shaft to increase its surface area and redistribute the impact force thereby reduces the pressure in case the shaft accidentally hit the pot when coupling or uncoupling it from the electric motor.

The stirrer is directly coupled to the electric motor of 0.94 HP which was sitting on an insulating material to prevent electric shock. The constructed machine is presented in Plate 1.

2.6. Performance evaluation

The test material was 100% yam flour ground to fineness and sieved with 0.85 mm sieve. A Mentra Electronic Precision Balance TL-5000 model weighing machine was used to weigh 350 g of yam flour needed for the test.



PART	DESCRIPTION
A	ENGINE COVER
B	ELECTRIC MOTOR
C	BUSHING
D	ENGINE SWITCH
E	ENGINE SEAT
F	COVER
G	STIRRER
H	POT
I	BOLT
J	HEATER HOUSING

Fig. 2. The exploded view of the machine.

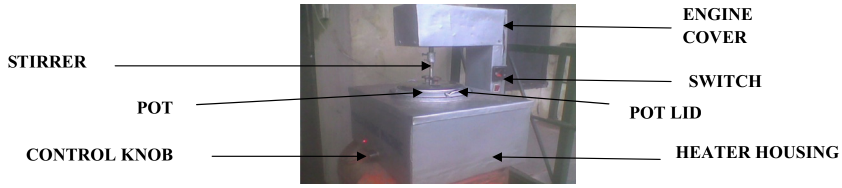


Plate 1. The *Àmàlà* making machine.

Table 1
Parameters of yam flour paste from the survey.

Wt. of flour (g)	Vol. of water (Litre)	Wt. of water (g)	Number of turning/stirring	Final temp. (°C)	Time (min)
19,200	16	18,033.76	15	70	10
24,000	20	22,542.22	25	80	12
27,000	22.5	25,359.98	30	70	14
2800	2	2254.22	10	70	7
5040	4	4508.44	15	73	9
4000	3	3381.33	20	70	8
5200	4	4508.44	15	70	8
5600	5	5635.55	20	73	9

The pot was filled up to1.8 Litre with water and allowed to boil using the heater. Immediately the water got boiled, the stirrer was switched on before the yam flour was applied manually, this is to avoid ball formation after preparation. The whole content was left to stir together until the smooth paste was achieved. The test was repeated for 2 more times with the same quantity of yam flour. The time taken, the temperature, the volume and the weight of the paste produced were recorded for each preparation. The test was repeated with 400 g, 450 g, and 500 g in triplicates using 1.4 Litre, 1.0 Litre, and 0.6 Litre of water. The input weight (weight of water and yam flour) was compared with the average weight of the paste at different volumes of water, to discover any relationship between them. The prepared *àmàlà* was served to 10-man panel for sensory evaluation based on scoring difference and preference tests. The evaluation was based on the scale of 1-9 for preference test, where 1stands for, dislike very much and 9 means like extremely and 1-6 for scoring difference test.

2.7. Statistical analysis

After construction, the machine was tested and the results of the test carried out were subjected to a 2-way Analysis of Variance (ANOVA) to determine if the various weight of the *àmàlà* (yam flour paste) differs significantly in terms of weights of yam flour and weights of water, and the interaction between amount of flour and water. It was also conducted on temperature and the density of the paste produced.

3. Results and discussion

3.1. The preliminary survey

The results of preliminary survey conducted through questionnaire administered to 16 women within Idi-Ape and Abayomi areas of Iwo Road, Ibadan are presented in Tables 1 and 2.

The results of yam flour paste (*Àmàlà Isu*) in Table 1 show that the maximum amount of flour being used is 27 kg which was mixed with 22.5 Litre (25.36 kg by weight) of boiling water, which was turned 30 times within 14 min, the paste has a temperature of 70 °C. Also, 2.8 kg which is the minimum amount of flour as revealed by Table 1 mixed with 2 Litre (2.25 kg) of boiling water was turned 10 times within 7 min, and has 70 °C as the paste final temperature.

The parameters recorded for cassava flour paste through the administered questionnaire presented in Table 2. It can be seen that the maximum amount of flour was 33.6 kg mixed with 30 Litre (33.813 kg) of boiling water, turned for 20 times within 15 min and the paste produced has 70 °C of temperature, while at minimum amount of flour (1.2 kg) which was mixed 1 Litre (1.127 kg) of water turned 11 times within 8 min, 70 °C of temperature was maintained.

In comparison between the two types of àmàlà, it was observed that the ratio of yam flour required to water is higher (27 kg of flour to 25.36 kg of water) than cassava flour, where 33.6 kg of flour mixed with 33.8 kg of water. It can be deduced that in preparing *àmàlà* isu, more flour is required than water, while more water is required in preparing *àmàlà lafun* than cassava flour, though the differences are minimal.

Also the final temperature of *àmàlà Isu* ranges from 70–80 °C while that of *àmàlà láfún* is constant at 70 °C all through. This can be attributed to the fact that during preparation of *àmàlà Isu*, the heat source was not totally removed until the paste was done, unlike *láfún* where immediately flour is put into the boiling water, the content was removed from heat source.

It can also be observed that time taken for the highest number of turning in *àmàlà Isu* is 30 turning for 14 min which is relatively smaller than time taken for *àmàlà lafun* with the

Table 2
Parameters of Cassava flour paste from survey.

Wt. of flour (g)	Vol. of water (Litre)	Wt. of water (g)	Number of turning/stirring	Final temp. (°C)	Time (min)
17,600	15	16,906.65	20	70	10
33,600	30	33,813.3	20	70	15
4800	4	4508.44	12	70	9
2080	1	1127.11	10	70	9
2400	2	2254.22	13	70	9
3600	3	3381.33	11	70	9
1200	1	1127.11	11	70	8
32,000	30	33,813.3	20	70	13

Table 3
Machine evaluation with 1.8 Litre of water.

	M_f+M_w (kg)	M_f (kg)	M_p1 (kg)	Time$_{Res}$ (min)	Temp$_{Final}$ (°C)	M_p2 (kg)	Time$_{Res}$ (min) 2	Temp$_{Final}$ (°C)	M_p3 (kg)	Time$_{Res}$ (min) 3	Temp.$_{Final}$ (°C)
$V_{1.8}$	2.3788	0.35	2.2029	5.00	85	2.3055	4.50	90	2.2776	4.58	90
	2.4288	0.40	2.4026	4.50	90	2.3427	4.58	90	2.4231	5.00	90
	2.4788	0.45	2.4056	4.50	90	2.4590	4.58	89	2.4307	4.38	89
	2.5288	0.50	2.7326	4.48	91	2.5937	3.55	89	2.7071	4.00	90
$V_{1.4}$	2.2268	0.35	1.8555	4.50	81	2.0010	3.10	90	1.9207	3.43	90
	2.2760	0.40	2.0303	4.13	85	1.7900	4.51	87	1.9979	4.40	81
	2.3268	0.45	2.1195	5.20	85	2.2024	5.56	85	2.1716	6.05	87
	2.3768	0.50	2.2590	3.10	85	2.1026	3.12	85	2.3483	3.47	86
$V_{1.0}$	1.8780	0.35	1.505	3.04	85	1.4960	3.28	85	1.5220	3.18	85
	1.9280	0.40	1.446	3.25	79	1.7220	3.01	80	1.3280	3.25	78
	1.9780	0.45	1.464	3.27	79	1.5160	3.50	77	1.8990	3.50	82
	2.0280	0.50	1.563	3.47	80	1.7590	3.30	81	1.6980	3.20	78
$V_{0.6}$	1.0843	0.35	1.0222	3.52	77	1.1290	3.20	81	1.0713	3.45	81
	1.1343	0.40	1.2426	3.09	78	1.0971	2.50	74	1.2687	4.34	70
	1.1843	0.45	1.1604	3.10	70	1.2968	3.20	74	1.1397	5.00	78
	1.2343	0.50	1.4752	3.00	75	1.2024	3.16	82	1.3820	4.18	66

Note: M_f+M_w = mass of the input M_f = mass of the flour M_w = mass of water M_p = mass of the paste time$_{Res}$ = residence time temp$_{final}$ = final temperature $V_{1.8}$ = 1.8 Litre of WATER $V_{1.4}$ = 1.4 Litre of water $V_{1.0}$ = 1.0 Litre of water $V_{0.6}$ = 0.6 Litre of water.

highest number of turning (i.e. 20 turning within 15 min), this may be attributed to stiffness of the *àmàlà,* which means that, *àmàlà láfún* is stiffer than *àmàlà isu*.

The ratio of flour to water was 52:48 and 51:49. The percentage of flour used in preparing both types of *àmàlà* was about equal (52% of yam flour and 51% of cassava flour), though the percentage of yam flour was more than the cassava flour percentage by 1%. In both, it was clearly shown that the percentage of flour should be more than the percentage of water.

3.2. Weight of paste produced

The result of the test of the *Àmàlà* Making Machine at different volume of water from maximum pot capacity of 1.8 Litre to minimum pot capacity of 0.6 Litre of boiling water was presented in Table 3.

The results of the variance analysis revealed that the effect of input on weight of *àmàlà* produced is significantly different ($P<0.05$). The difference in weight was due to change in amount of input at different stages, for example, the maximum amount of input at 1.8 Litre is 2.53 kg and minimum is 2.38 kg, while at 0.6 Litre of water 1.23 kg is the maximum amount of input and 1.08 kg is the minimum. The interaction between the various volume of water and various amount of yam flour was acceptable ($P>0.05$). This indicates that there was significant interaction between the volume of water and amount of flour used, that is, the weight of paste produced depends on weight of water and flour that mixed together. Also, it was observed that the weight of the input is higher than the weight of the paste produced in most

Table 4
Density of the paste.

Volume of water (Litre)	Density at 350 g	Density at 400 g	Density at 450 g	Density at 500 g
1.8	1223.83	1334.78	1336.44	1518.11
	1280.83	1301.50	1366.11	1440.94
	1265.33	1346.17	1350.39	1503.39
1.4	1325.36	1450.21	1513.93	1614.00
	1429.29	1278.57	1445.48	1501.86
	1371.93	1427.07	1551.14	1677.35
1.0	1504.60	1446.20	1463.60	1562.70
	1495.50	1721.70	1516.00	1759.30
	1522.20	1327.80	1899.00	1697.70
0.6	1703.67	2071.00	1974.00	2458.67
	1881.67	1828.50	2161.33	2004.00
	1785.50	2114.50	1899.50	2303.33

Table 5
Scoring test with 1.8 Litre of water.

Attributes	350 g	400 g	450 g	500 g
Colour	5	5	5	5
Taste	6	6	6	6
Mouldability	6	5	3	2
Texture	6	5	2	2
Aroma	2	2	2	2

Table 6
Scoring test with 1.4 Litre of water.

Attributes	350 g	400 g	450 g	500 g
Colour	5	5	5	5
Taste	6	6	6	6
Mouldability	3	2	2	2
Texture	2	2	2	2
Aroma	2	2	2	2

Table 7
Scoring test with 1.0 Litre of water.

Attributes	350 g	400 g	450 g	500 g
Colour	5	5	NA	NA
Taste	6	6	6	6
Mouldability	2	2	1	1
Texture	2	2	2	2
Aroma	2	2	2	2

cases. This is evident at maximum volume (1.8 Litre) where the minimum input is 2.38 kg and produces 2.2 kg, 2.3 kg, 2.28 kg paste replicates, as none of these is up to the input.

Table 8
Scoring test with 0.6 Litre of water.

Attributes	350 g	400 g	450 g	500 g
Colour	5	5	NA	NA
Taste	6	6	6	6
Mouldability	2	2	1	1
Texture	4	3	2	2
Aroma	2	2	2	2

The reduction in weight of the output is due to the fact that some part of the input have escaped through evaporation, except in some cases where output is more than the input, as recorded at 1.8 Litre of water where 2.53 kg of input produced 2.73 kg, 2.59 kg and 2.71 kg of paste.

Though, at 0.6 Litre volume of water most of the paste weight were higher than their respective input, especially at maximum input (1.23 kg) where various amount of output are 1.48 kg, 1.20 kg and 1.3 kg, because cold water was added during preparation, due to the fact that at this volume of water pastes were so thick and almost caused the machine seizure, therefore the cold water that added was assumed to still have retained by the paste since cold water cannot evaporate. This is a good evidence of the machine effective performance in term of input to output weight.

3.3. Temperature of the paste

The temperature recorded during the test (Table 3), shows that the temperature reducedfrom 90–85 °C at 1.8 Litre to 82–66 °C at 0.6 Litre of boiling water, as the weight of the paste reduces from 2.73–2.2 kg at 1.8 Litre to 1.47–1.02 kg at 0.6 Litre of boiling water; this may be due to reduction in size of the paste available to store heat.

Table 9
Preference test with 1.8 Litre of water.

Attributes	350 g	400 g	450 g	500 g
Colour	8	8	8	8
Taste	8	8	8	8
Mouldability	1	2	7	8
Texture	1	2	7	8
Aroma	8	8	8	8
Overall acceptance	1	3	7	8

Table 10
Preference test with 1.4 Litre of water.

Attributes	350 g	400 g	450 g	500 g
Colour	8	8	8	8
Taste	8	8	8	8
Mouldability	1	2	8	8
Texture	1	2	8	8
Aroma	8	8	8	8
Overall Acceptance	1	3	7	8

Table 11
Preference test with 1.0 Litre of water.

Attributes	350 g	400 g	450 g	500 g
Colour	8	8	6	4
Taste	8	8	8	8
Mouldability	7	8	8	8
Texture	8	8	8	8
Aroma	1	2	7	8
Overall acceptance	7	8	6	4

Table 12
Preference test with 0.6 Litre of water.

Attributes	350 g	400 g	450 g	500 g
Colour	8	8	2	2
Taste	8	8	8	8
Mouldability	8	8	9	9
Texture	8	8	8	8
Aroma	8	8	8	8
Overall acceptance	8	8	2	2

3.4. Residence time of the paste

It was observed from Table 3, that the residence time reduced as amount of input and output reduced the minimum amount of input (2.38 kg) at 1.8 Litre of water produced 2.2–2.3 kg of *àmàlà* within 2.45–3.2 min, while minimum amount of input (1.08 kg) at 0.6 Litre of water produces 1.02–1.13 kg of *àmàlà* within 3.2–3.52 min. The time taken to prepare *àmàlà* by this machine is lesser when compare with manual method where 7 min is the minimum time used to prepare *àmàlà isu* (see Table 2), this shows that, use of machine to prepare *àmàlà* is time saving.

Table 13
Heat quantity of the paste.

Volume of water (Litre)	**Mass of the Flour** (kg)	Q_1 (KJ)	Q_2 (KJ)	Q_3 (KJ)	Q_{av} (KJ)
1.8	0.35	124.12	103.09	106.46	111.22
	0.40	103.10	106.47	210.16	139.91
	0.45	103.10	106.46	98.05	102.54
	0.50	102.26	106.46	82.07	96.93
1.4	0.35	103.10	44.21	58.11	68.47
	0.40	87.54	103.52	98.89	96.65
	0.45	135.53	147.67	168.27	150.49
	0.50	44.23	45.07	59.79	49.7
1.0	0.35	41.71	54.53	47.59	47.94
	0.40	50.54	40.45	47.18	46.06
	0.45	51.38	61.05	61.05	57.83
	0.50	59.78	52.64	61.09	58.1
0.6	0.35	61.89	48.44	48.44	52.92
	0.40	43.81	8.64	95.78	49.41
	0.45	44.22	48.44	124.12	72.26
	0.50	40.02	46.76	89.64	58.81

Note: Q = quantity of heat (KJ), Q_{av} = average of the heat quantity replicates.

Plate 2. Sample of 500 g flour in 1.8 Litre.

3.5. Density of paste

The density of the paste is presented in Table 4. It was observed that the density of the paste increased (1223.83 kg/m^3 at 1.8 Litre of water to 2303.33 kg/m^3 at 0.6 Litre of water) as the volume of water reduced, that is, down the table, and also along the various weight, since the water is kept constant and weight of the flour is increasing the product bulkiness will increase, therefore the density will also increase. This further established the fact that the density of a material varies inversely as its volume. This effect increases mouldability of the paste accordingly, though with more quantity of flour especially 450 g and 500 g, the paste acceptability reduces.

3.6. Sensory evaluation

Tables 5–8 presented the scoring test result, and Tables 9–12 presented the preference test at different volume of water. It was discovered that at maximum volume of the pot (i.e. 1.8 Litre)

Plate 3. Sample of 450 g flour in 1.4 Litre.

Plate 4. Sample of 400 g flour in 1.4 Litre.

Plate 5. Sample of 350 g flour in 0.6 Litre.

500 g of flour was adjudge the best then followed by the 450 g while both 350 g and 400 g were not acceptable, because of non smoothness and non mouldability. The best paste in terms of texture and mouldability was achieved with 350 g of yam flour at 1 Litre while 400 g of yam flour was good at 1.4 Litre. Both 450 g and 500 g of yam flour were too hard and whitish in colour compare to normal slightly brown of well cooked one, these make them not acceptable to serve despite having good texture and mouldable at 0.6 Litre of water (Table 13). The sample of *àmàlà* made with 500 g of flour using 1.8 Litre of water is shown Plate 2. This *àmàlà* was adjudged the best in terms of colour, mouldability and texture, by scoring difference and preference tests presented in Tables 5 and 8 respectively. It was graded 2 in scoring and 8 in preference tests. Grade 2 in scoring test means (Plates 3–7).

Plate 6. Sample of 400 g flour in 1.0 Litre.

Plate 7. Sample of 500 g flour in 0.6 Litre.

4. Conclusions

An *àmàlà* making machine was designed and constructed with materials that are readily available in the market, it was simple to operate with little or no special skill. It was designed to ease the process of *àmàlà* preparation.

The following conclusions could be drawn from this study:

(i) This machine can prepare *àmàlà* of 2.68 kg averagely by weight at average temperature of 90 °C within an average time of 4.01 min at maximum pot capacity (i.e. 1.8 Litre) which can feed two to four adults.
(ii) At minimum pot capacity (i. e. 0.6 Litre) the appropriate amount of the paste is 1.07 kg averagely
(iii) By weight at average temperature of 79.67 °C within average time of 3.39 min.
(iv) The machine was found to be more effective than the manual method, which requires much energy and can be stressful when considering the time taken, the human energy required, and hygienic situation.
(v) Both the electric motor and the heater have equal power rating of 0.94 HP with 220 V. This makes it suitable for individual household. The machine was well insulated to avoid electric shock.
(vi) During operation the stirrer should be switched on before supplying yam flour.

Recommendations

Further work can be done on the machine by;

(i) Incorporating a yam flour metering mechanism.
(ii) Incorporating a sensor with an indicator that will stop the stirrer immediately the smooth paste is achieved.

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